Effect of liming management on the water quality in *Colossoma macropomum* ("Tambaqui"), ponds.

SIPAÚBA-TAVARES[1], L.H., GOMES[2], J.P.F. dOS S. & BRAGA[3], F.M. dE S.

[1]**Universidade Estadual Paulista, Centro de Aquicultura Via de Acesso Prof. Paulo Donato Castellane s/n, Jaboticabal, São Paulo, Brasil, 14884-900. e-mail: sipauba@caunesp.unesp.br**

[2]**Universidade Camilo Castelo Branco, Estrada Projetada s/n km 3, Fernandópolis, SP, Brasil.**

[3]**Universidade Estadual Paulista, Departamento de Zoologia/IB, Av. 24 A 1515, Rio Claro, SP, Brazil, 13500-000, e-mail: fmsbraga@ms.rc.unesp.br**

ABSTRACT: Effect of liming management on the water quality in *Colossoma macropomum* (tambaqui) ponds. **The objective of this study was to evaluate three different doses of lime on the water quality of fishponds populated with *Colossoma macropomum* ("tambaqui") with water exchange. Considering the limnological variables, chlorophyll-*a*, alkalinity, temperature, dissolved oxygen, nutrients and free CO_2 were not significantly different (P>0.05) among treatments. Total phosphorous presented the highest concentrations and ammonia levels tended to decrease in the treatment with the highest liming amount (T_3). The nitrate concentrations were higher in the inlet water. In general, metals and organic matter in the sediment decreased during the experiment. Liming did not affect the limnological variables, with the exception of conductivity that tended to increase and Free CO_2 to decrease with increasing liming concentration. Indicated lime quantity for the studied fishpond was 75 g/m² (T_1), due to the acid pH of the sediments.**

Key-words: **fish pond, liming, water quality.**

RESUMO: Efeito do manejo de calagem em viveiros de *Colossoma macropomum* (tambaqui). **O objetivo deste estudo foi avaliar três diferentes dosagens de cal na qualidade da água em viveiros de criação de *Colossoma macropomum* (tambaqui), com fluxo contínuo de água. Dentre as variáveis limnológicas analisadas, clorofila-*a*, alcalinidade, temperatura, oxigênio dissolvido, nutrientes e CO_2 livre não apresentaram diferenças significativas (P>0,05) entre os tratamentos. O fósforo total apresentou as maiores concentrações e a amônia tendeu a decrescer no tratamento com maior quantidade de calagem. O nitrato apresentou as maiores concentrações na água de abastecimento, enquanto nos viveiros, a amônia foi a dominante. Em geral, houve uma redução dos metais e matéria orgânica do sedimento durante o período experimental. A dosagem de calagem não afetou as variáveis limnológicas estudadas, com exceção da condutividade que tendeu a aumentar, e o CO_2 livre a diminuir, com o aumento da dosagem de cal na água. A quantidade utilizada neste estudo foi de 75g/m² (T_1), indicando a necessidade de calagem nos viveiros analisados devido ao pH ácido dos sedimentos.**

Palavras-chave: **viveiro, calagem, qualidade de água.**

Introduction

Liming is a simple and usual procedure used in aquaculture to neutralize acidity and increase alkalinity, thus increasing fishpond productivity. The calcium and magnesium contained in the lime may be absorbed by the aquatic biota, adsorbed by the soil or dissolved in the water.

Liming is a necessary and important procedure in any fishpond, and consists of lime addition to the water and sediment, in a range of concentrations according to pond dimensions.

In acid water, lime increases the pH and consequently, aquatic life survival, reproduction and growth rates. The availability of phosphorus contained in the fertilizer

is increased due to a higher microbial activity, to a decrease of organic matter in the sediment, and nutrient recycle. The benefits of liming are attributed to a higher availability of carbon dioxide for phytoplankton growth (Boyd & Tucker 1998). Bhaumik et al. (1991) verified that in ponds where calcium oxide was applied there was a reduction in fish mortality caused by parasites.

In general, the problems with liming are related to inappropriate management, with lack or excess lime being added to the ponds, which may cause problems to the water quality further on.

Liming is recommended when hardness and alkalinity are below 20 mg/L. However, alkalinity is the best indicator, since in many fishponds these two parameters display an inverse relationship (Boyd & Tucker, 1998).

According to Arana (1997), the practice of liming in aquaculture ponds and tanks continues to be very polemical due to lack of data and conditions inherent to culture systems, as well as heterogeneity, medium dynamics and the different types of soils where fishponds are located.

For systems where water exchange occurs only during periods of high precipitation or by replacement due to evaporation losses, some liming techniques are already employed leading to an equilibrium between water and sediment and adequate conditions inside the fishpond. However, in fishponds with continuous water flow there is still no definite technique because several factors affect the dynamics of these systems. Residence time, sediment features and culture management are factors that play an important role in improving water quality, thus resulting in high fish production that can be consumed in the market.

Tambaqui (*Colossoma macropomum*), a tropical freshwater fish from Amazonian basin in Brazil, has shown great potential for aquaculture. They can survive long periods of hypoxia, and in ponds they can feed initially on zooplankton during 29 days, modifying feeding habits later. When they start selecting inert particles, ration can then be added as food (Sipaúba- Tavares et al., in press).

Due to the importance of liming, this work aimed at evaluating the effects of three different concentrations on the water dynamics of fishponds populated with tambaqui (*Colossoma macropomum*).

Material and methods

Period and Sampling site

The study was conducted at Aquaculture Center (21^0 15' S; 48^0 18' W) of the Universidade Estadual Paulista, Jaboticabal, São Paulo, Brazil, during the rainy period (November 1998 to February 1999) and high fish production. Three 54m^3 fishponds (5.0m x 9.0m x 1.2m) were populated with tambaqui (*Colossoma macropomum*) at 1 fish/m^2 density. Continuous water flow provided 5% daily exchange rate of the rearing volume. The fish were feed a supplementary diet containing 25% crude protein at rates of 3% of their average live weight.

Four sampling sites were selected for the measurements, one in the inlet water (IW) and 3 different ones in each fishpond (T_1, T_2 and T_3).

Along the 72 days culture period, samples were collected daily, during 15 days, every three days during other 15 days and weekly during the last 42 days, from the sampling sites. All samples were collected between 8:30 A.M. and 10:30 A.M. hours, using a Van Dorn bottle (1L) and always at the same site and at 0.60m of depth (in the ponds only).

Liming

Three liming treatments were investigated: a) 75 g/m^2 (T_1); b) 150 g/m^2 (T_2) and c) 300 g/m^2 of lime (T_3). Commercially available lime was applied homogeneously on the pond bottom and sidewalls and left for 24 hours. Ponds were then filled with water for the beginning of the trial, according to procedure adopted at the Aquaculture Center, where T_1 dosage is normally applied once a year.

Limnological characteristics

The limnological variables and corresponding methods are presented in Tab. I.

Wind speed was monitored using a portable anemometer AM 4201, expressed in km/h, and measured at 1.9m high. Average total precipitation was measured using a pluviometer placed at the "Estação Agroclimatológica, in the Departamento de Ciências Exatas, UNESP (Jaboticabal)".

Table I: Limnological characteristics analysed.

Limnological characteristics	Methods
Residence Time	Volume/Flow
Transparency	Secchi disk
Dissolved Oxygen	Horiba U 10
Temperature	Horiba U 10
pH	Horiba U 10
Electrical Conductivity	Horiba U 10
Turbidity	Horiba U 10
Total Alkalinity and Inorganic Carbon	Mackereth et al. (1978)
Ammonia	Koroleff (1976)
Nitrite, Nitrate, Total Phosphorus and Orthophosphate	Golterman et al. (1978)
Chlorophyll-*a*	Nush (1980)

Sediment

Sediment samples were collected at the beginning and end of the experiment, at five different sites inside the fishpond at varying depth between 0 and 5 cm. The studied variables were pH, organic matter (OM), calcium (Ca), sulfur (S), magnesium (Mg), potassium (K), basis saturation index (V) and cationic exchange capacity (CTC), according to methodology described by Raij et al. (1987).

Growth

Fish length and weight were determined using a graded scale and a 1-gr precision balance, respectively. Values were registered at the beginning and end of the experiment. Survival rate in each pond was also determined.

Statistical Analysis

The limnological variables and fish length and weight were analyzed using the non-parametric Kruskal-Wallis test (Siegel, 1975). Since the variances were heterogeneous, the Dunn test was used (Vanzolini, 1993).

Results

Limnological characteristics

Ammonia, orthophosphate ($P\text{-}PO_4$), dissolved oxygen (DO), and total CO_2 were not significantly different (P>0.05) among treatments. On the other hand, temperature, alkalinity, nitrite, nitrate, total phosphorus (Total-P), and chlorophyll-*a*, were not significantly different (P>0.05) among treatments and inlet water (Tab. II).

Inlet water was higher in respect to total-P, nitrate and DO. Turbidity was nearly 30 times higher in the inlet water when compared to treatments T_1 –T_3, thus showing that transparence increased as lime concentration increased (Tab. II).

Table II: Results from the Kruskal-Wallis (H) and Dunn (D) tests for limnological characteristics, for the three treatments investigated (T_1, T_2 and T_3) and inlet water (IW) during the period. * = P < 0.05, ns= not significant (the continuous line indicates similarities (P<0.05).

Limnological Characteristics	Units	H	D			
Transparency	Cm	9.86*	T_1		T_2	T_3
Temperature	^{0}C	2.45 ns	T_1	T_2	T_3	IW
Turbidity	NTU	10.72*	T_1	T_2	T_3	IW
Conductivity	mS/cm	50.80*	T_2	T_3	T_1	IW
pH		46.48*	T_1	T_3	T_2	IW
Dissolved oxygen	mg/L	23.70*	T_1	T_2	T_3	IW
Alkalinity	mg/L	7.7 ns	T_1	T_2	T_3	IW
Bicarbonate	mg/L	22.90*	IW	T_1	T_2	T_3
Free CO_2	mg/L	30.89*	T_1	IW	T_2	T_3
Total CO_2	mg/L	23.21*	T_1	T_2	T_3	IW
Nitrite	mg/L	0.79 ns	T_1	T_2	T_3	IW
Nitrate	mg/L	6.17 ns	T_1	T_2	T_3	IW
Ammonia	mg/L	21.66*	T_1	T_2	T_3	IW
Total –P	mg/L	2.32 ns	T_1	T_2	T_3	IW
$P\text{-}PO_4$	mg/L	18.69*	T_3	T_1	T_2	IW
Chlorophyll *a*	mg/L	7.75 ns	T_1	T_2	T_3	IW

In general, treatment T_2 was not significantly different from T_3 with the exception of temperature, turbidity and conductivity (Tab. II and III).

The slightly short residence time (2 to 4 days) promoted higher medium oxygenation, with average concentrations above 4 mg/L for different treatments. Even with residence time slightly longer in T_3 (4.01 days), DO was above 4.4mg/L (Tab. III).

Table III: Means of limnological characteristics of the fish ponds with liming levels of 75g/m² (T_1); 150g/m² (T_2); 300g/m² (T_3) and inlet water (IW) during the period.

Limnological Characteristics	Treatments T_1	T_2	T_3	IW
Residence time (days)	2.04	2.84	4.01	*
Transparency (cm)	85.04	101.5	107.92	*
Temperature (^{0}C)	26.71	27.19	26.39	26.72
Turbidity (NTU)	3.94	0.96	0.85	31.25
Conductivity (mS/cm)	30.15	35.23	48.11	23.92
pH	6.71	7.33	7.58	7.05
Dissolved oxygen (mg/L)	4.04	4.7	4.46	7.84
Alkalinity (mg/L)	35.85	42.92	44.08	31.23
Bicarbonate (mg/L)	43.67	52.11	53.46	38.23
Free CO_2 (mg/L)	28.89	5.89	3.59	8.98
Carbonate (mg/L)	0.02	0.02	0.03	0.004
Total CO_2 (mg/L)	72.58	58.11	56.96	47.21

* not measured

Treatment T_1 presented acid pH, which reflected directly on high free CO_2 concentrations (28.89 mg/L), higher than in the other treatments and differing significantly ($P<0.05$) only from T_3, (Tab. II and III).

Among inorganic carbon, the most abundant was bicarbonate, which did not differ significantly ($P>0.05$) for T_1 and the inlet water (IW). However, these differed significantly from T_2 and T_3 ($P<0.05$), with higher concentrations observed in T_3 and lower in T_1 (Tab. II and III).

Conductivity was above 30μS/cm, with the highest values found for treatment T_3 (48.11μS/cm) and the lowest in the IW (23.92μS/cm). The inlet water was not significantly different ($P>0.05$) from treatment T_1, that presented lower average values, 30.15μS/cm (Tabs. II and III).

In general, the nutrients were not significantly different ($P<0.05$) among treatments, differing only from inlet water as for ammonia, with higher concentrations for T_1. Although not significantly differing among treatments, ammonia decreased with increasing lime concentration in the medium. On the other hand, higher nitrate concentrations in the inlet water can be related to high oxygen concentrations and water current that promotes the nitrifying process. Lower concentration of nitrite in the water may be related to continuous water flow and short residence time (Fig. 1; Tab. II).

Total-P concentration was highest in the treatment with highest lime concentration (T_3), with an average of 0.39mg/L and lowest, (0.33mg/L) in T_2. On the other hand, P-PO_4 displayed an inverse behavior, with a higher concentration in T_2 (0.16mg/L) and, lower in T_3 with 0.13mg/L. However, both nutrients did not present significant differences ($P>0.05$) among the studied treatments (Fig. 1; Tab. II).

Chlorophyll-*a* presented low concentrations with no significant differences ($P>0.05$) among treatments, which can be related to short residence time and continuous water flow washing away part of the phytoplanktonic biomass (Fig. 1; Tab. II).

Average wind speed throughout the period was 2.76km/h, with the lowest (0.3 km/h) and highest (7.0km/h) values obtained during December, with the latter being accompanied by heavy rainfall.

During the period of study, mean precipitation was 324.7mm in December, 415.9mm in January and 192.1mm in February.

Growth

No fish mortality was observed throughout the period. However, growth rate and weight gain were not effective. Weight gain was not significantly different ($P>0.05$) for treatments T_1 and T_2. However, treatments T_1 and T_3 were significantly different ($P<0.05$), and displayed 405 and 322.5g weight gain, respectively. Growth rate was not significantly different ($P>0.05$) among treatments during the period. The highest value (27.86cm) was observed for T_2, which did not differ from the initial length of 22.99cm (Tab. IV).

Table IV: Final and initial mean weight (g) and length (cm) of *Colossoma macropomum* (tambaqui) at different treatments (T_1= 75g/m² lime; T_2= 150g/m² lime; T_3= 300g/m² lime).

Treatments	Stocking density	Initial fish stock		Final fish stock	
		Mean fish length (cm)	Mean fish weight (g)	Mean fish length (cm)	Mean fish weight (g)
T_1	45	24.42	223.00	24.75	405.00
T_2	45	22.99	161.00	27.86	300.00
T_3	45	23.73	160.50	26.00	322.50

Sediment

Sediment pH remained acid throughout the experiment, decreasing slightly in treatments T_2 and T_3. Base saturation index (V) decreased almost 50% due to sediment acidity at the end of the experiment (Tab. V).

Phosphorus in the sediment also decreased during the period, with the exception of treatment T_2. Total-P in the sediment increased in treatments T_1 and T_3, and decreased in T_2. A phosphorus loss from the sediment to the water column may have contributed to high total-P levels in the water. However, liming also contributed to phosphorus availability in the water, since not all the material contained in the lime dissolves at once (Tab. V).

Organic matter, calcium, sulfur, CTC, potassium and magnesium decreased markedly throughout the experiment. The marked decrease of these compounds in the sediment may be related not only to the acid pH, but also to the continuous water flow whose outlet was close to the sediment and to the heavy rains during the period, which probably washed away great part of the material contained in the fishpond sediment (Tab. III and V).

Table V: Final and initial mean concentrations (mg/L) of potassium (K), calcium (Ca), phosphorus (P), magnesium (Mg), organic matter (OM), sulfur (S), base saturation index (V,%), cationic exchange capacity (CTC, mmolc/L) and pH in the sediments of different treatments (T_1= 75g/m² lime; T_2= 150g/m² lime; T_3= 300g/m² lime).

Treatments	Initial								
	K	Ca	P	Mg	OM	pH	CTC	S	V
T_1	78.2	3,767	590.0	1,726	0.03	5.8	187.0	5,355	89.0
T_2	89.9	2,204	60.0	1,118	0.05	5.5	133.3	3,312	77.0
T_3	86.0	2,765	190.0	1,070	0.05	5.7	140.2	3,694	82.0
	Final								
	K	Ca	P	Mg	OM	pH	CTC	S	V
T_1	27.4	801.6	140.0	194.5	0.01	5.2	58.7	920.2	49.0
T_2	31.3	801.6	147.0	145.9	0.01	4.8	67.8	859.3	40.0
T_3	39.1	721.4	99.0	97.2	0.01	4.7	63.0	737.5	36.0

Discussion

One of the main objectives of liming is to increase the alkalinity level above 20mg/L, by increasing water pH and making the phosphorus contained in the fertilizer available, thus removing carbon dioxide and decreasing carbonate ions that can lead to decreasing pH of the medium (Boyd & Tucker, 1998).

A close relationship was also observed between increasing lime levels and decreasing turbidity, when lime concentration in the fishpond was 300g/m²; turbidity was 0.85 NTU and water column was almost totally transparent. Therefore, inadequate liming or high concentrations may cause submerse plants to appear due to excessive light penetration in the system. Flow-through may also increase water transparency due to lixiviation of great amount of materials contained in the fishpond.

Probably the short residence time affected concentrations of chlorophyll-*a* washing away of large part of the algae in the medium, since liming increases carbon availability for photosynthesis, and consequently phytoplanktonic biomass.

Clayton et al. (1998) while studying the effect of liming in acid streams verified that water flow was the main controller of water quality conditions and in periods with long water flow, the water displayed much better quality, due to a longer contact time between the medium and the lime. The same authors observed that liming influenced positively fish reproduction, mainly trout.

In this study, fish reproduction was not evaluated. However, liming did not affect survival of tambaqui, and growth rate was neither effective nor significantly different ($P>0.05$) throughout the experiment. On the other hand, weight gain almost doubled for all treatments and the highest weight gain was observed for the treatment containing 75g/m² of lime.

Increasing lime concentrations did not affect significantly (P>0.05) nutrient levels in the water. With respect to total-P, high concentrations were observed in the water column probably due to non-digested food particles, feces and also phosphorus lost from the sediment to the water, since a marked reduction of phosphorus in the sediment was observed at the end of the experiment. In addition to these factors, most of the liming material does not dissolved at once, and as it settles through the water, phosphorus reacts with it and is lost from solution (Boyd & Tucker, 1998).

According to Masuda & Boyd (1994), acid soils around 4.6 to 5.3 presented higher solubility of phosphorus in the medium, which resulted in increased total alkalinity, calcium concentrations and higher availability of inorganic carbon for photosynthesis. Sediment pH in this study was in the 4.8 to 5.8 range, which probably increased liberation of this component from the sediment to the water column, with much higher concentrations than the nitrogen compounds indirectly added to the ponds via ration.

Calcium content in the water was not evaluated. However, a reduction higher than 64% was observed in the sediment, what might indicate its availability.

Liming affected positively and directly organic matter decomposition accumulated in the sediment, which was reduced to less than half probably due to an increased bacterial activity in the ponds. This effect is extremely important to the ponds, since high concentrations of organic matter in the sediment may result in anaerobic conditions at the soil-water interface, which can lead to inadequate water quality.

Liming is a procedure that needs more attention since conditions of the sediment and at the sediment/water interface influence directly water quality, and consequently production. Ponds that do not need liming are those whose sediment pH is above 7, and pond water alkalinity is above 60 mg/L (Sonnenholzener & Boyd, 2000).

According to Boyd & Tucker (1998), strongly fertilized tropical fishponds require alkalinity of approximately 75mg/L in order to obtain high production.

In general, the studied fishponds present alkalinity of about 23 to 40mg/L, and very low carbonate in the medium, producing fish of size and weight compatible with the consumer market (Sipaúba- Tavares et al., 1999).

From the treatments investigated, T_1 presented adequate nutrient concentrations, chlorophyll-*a*, lower values of conductivity and alkalinity above 20mg/L. In addition, fish weight was higher than in the other two treatments, and pH was slightly more acid but still adequate for planktonic community growth, which are the basic components of the aquatic trophic chain (Sipaúba-Tavares et al., 2001).

Attention should be paid at the water outlet, since the continuous water flow with cascade system, means that water from one pond is passed to the next.

The different lime dosages in the water did not cause significant differences among treatments. However, conductivity tended to increase with increasing lime concentration and fish yield was higher in ponds with lower lime dosages (T_1), with bicarbonate and alkalinity displaying values appropriate for fish culture. The use of dosages higher than $75g/m^2$ would be a waste of money. Liming procedure should be applied in the studied ponds, since the sediment had acid character, which can cause changes in the water conditions that affect directly the quality of the product.

Suggestions to apply best management practices (BMPs) in the studied ponds:

1)- It is advisable to build a biofilter system at the pond water outlet or at the effluents due to loss of nutrients and organic matter from the medium.

2)- Supplying water should be monitored frequently mainly in flow-through systems, because part of the liming material is not dissolved, and may be washed out from the pond, thus affecting directly the next pond.

3)- Frequent cleaning should be performed at pond water inlet and outlet, and a residence time of about 4 to 8 days for is advisable this pond size thus ensuring adequate water quality and fish production.

4)- Care should be taken with respect to lime management, by evaluating the necessity of frequent liming through limnological characteristics monitoring in the system. In this case, treatment T_1 was the most effective.

5)- Metals in the water was not monitored, but liming caused a loss of more than 50% of metals in the sediment (Tab. V). Therefore, during harvesting the fishpond should not be emptied completely, leaving 20 cm of water above the sediment. This water should be discarded after approximately 72 hours in order to avoid these metals to be released to the water column and be washed away to the subsequent fishpond.

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